Upgrade of European XFEL beam shutters for full beam operation

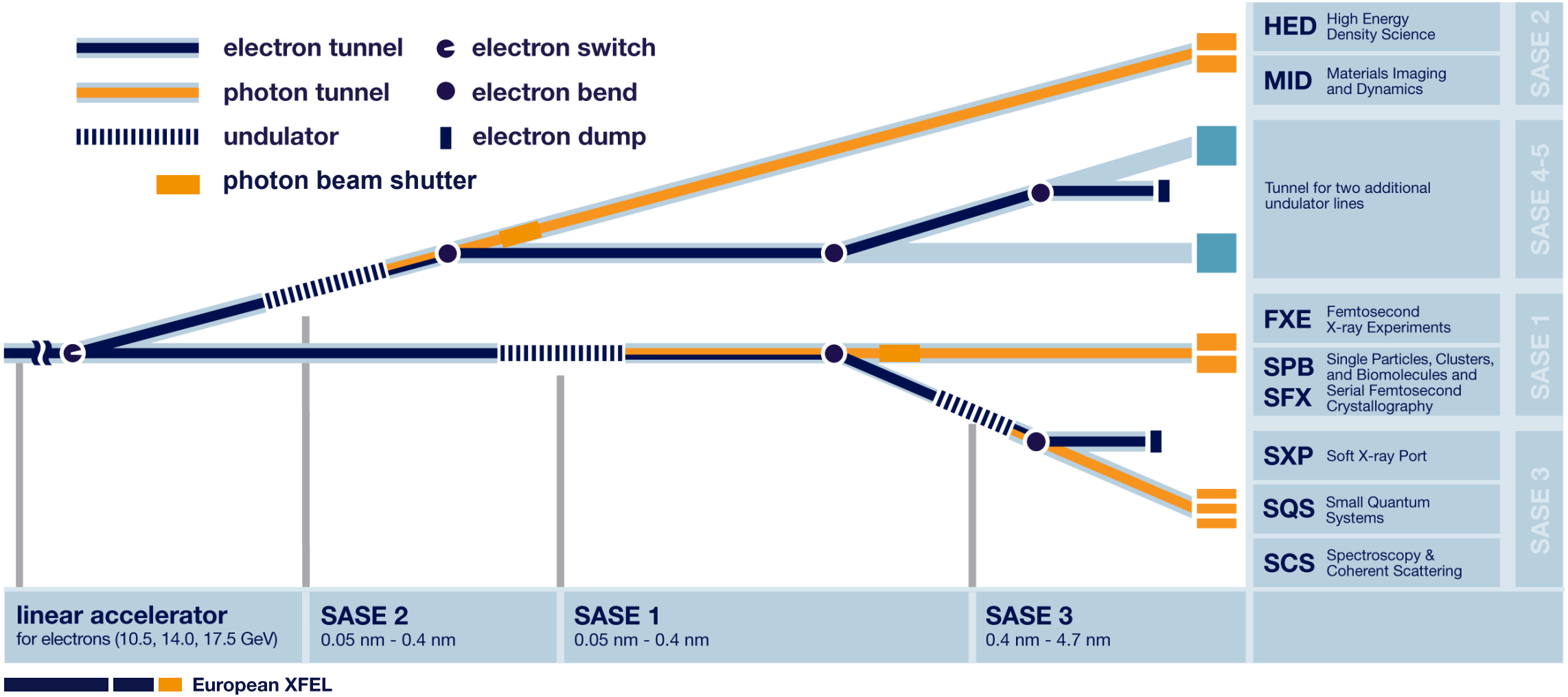
Martin Dommach
European XFEL

Beijing, November 7th 2023

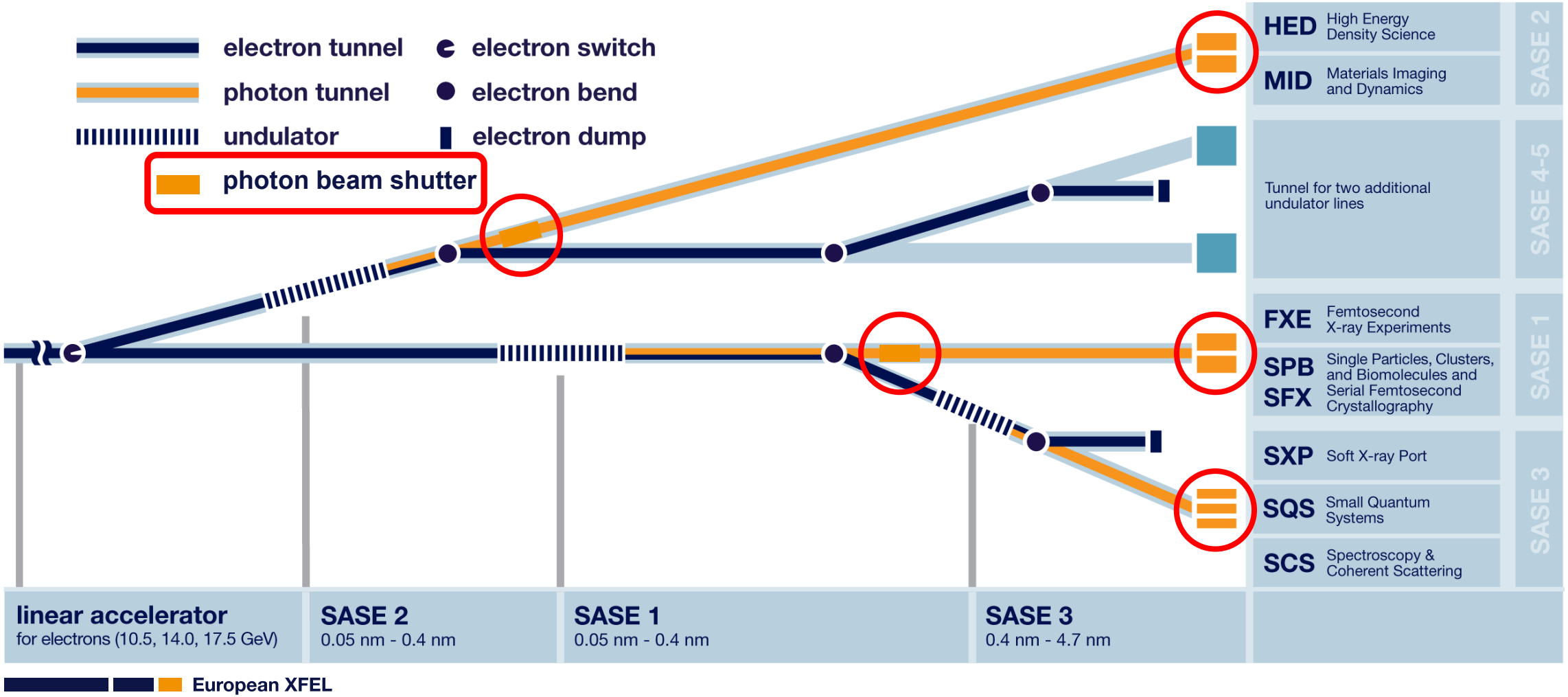
Outline

- Overview European XFEL and SASE2 beamline
- Previous frontend design
- Material tests
- New frontend design
- Burn-through detection
- Conclusion

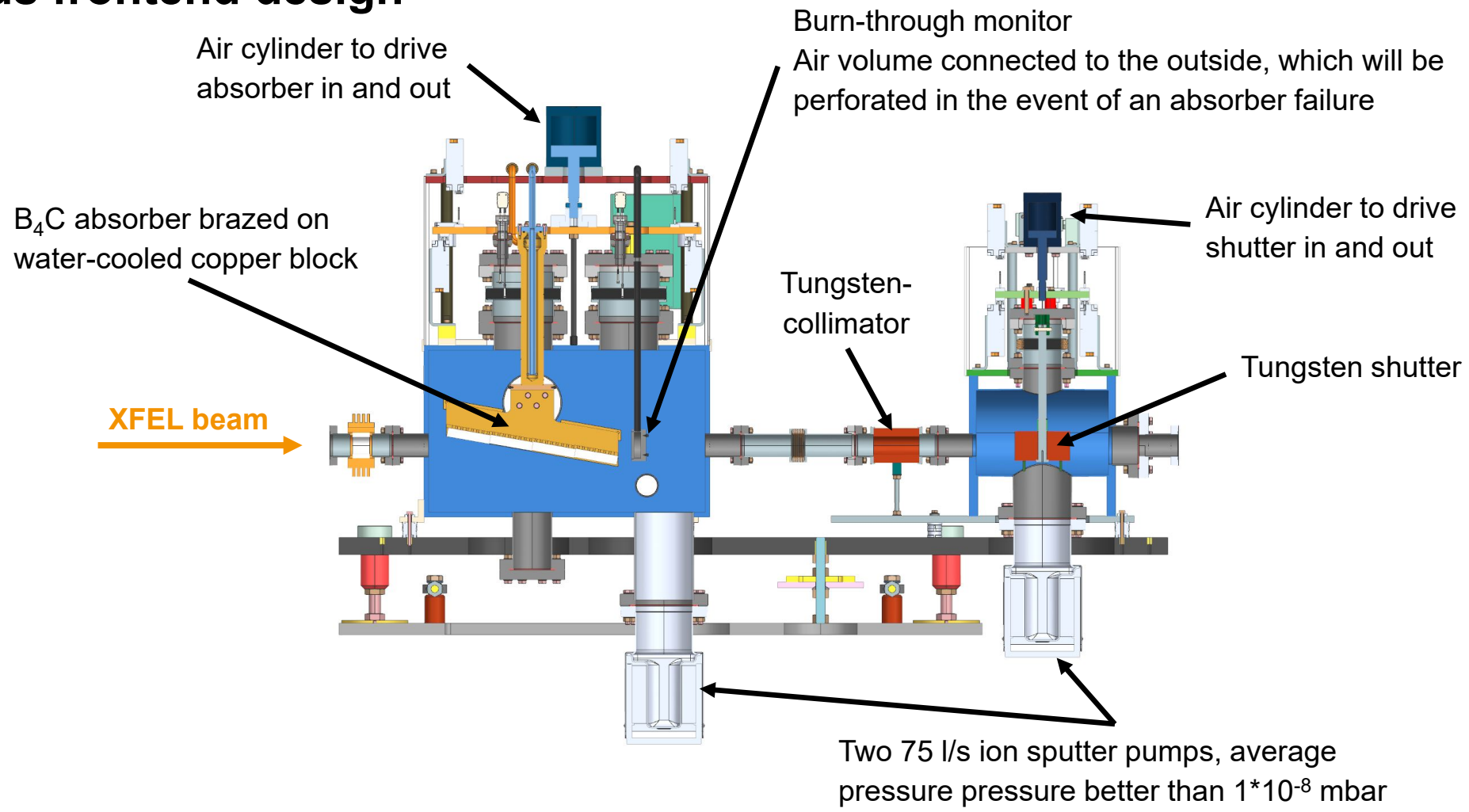
European XFEL beamline layout and experiment stations



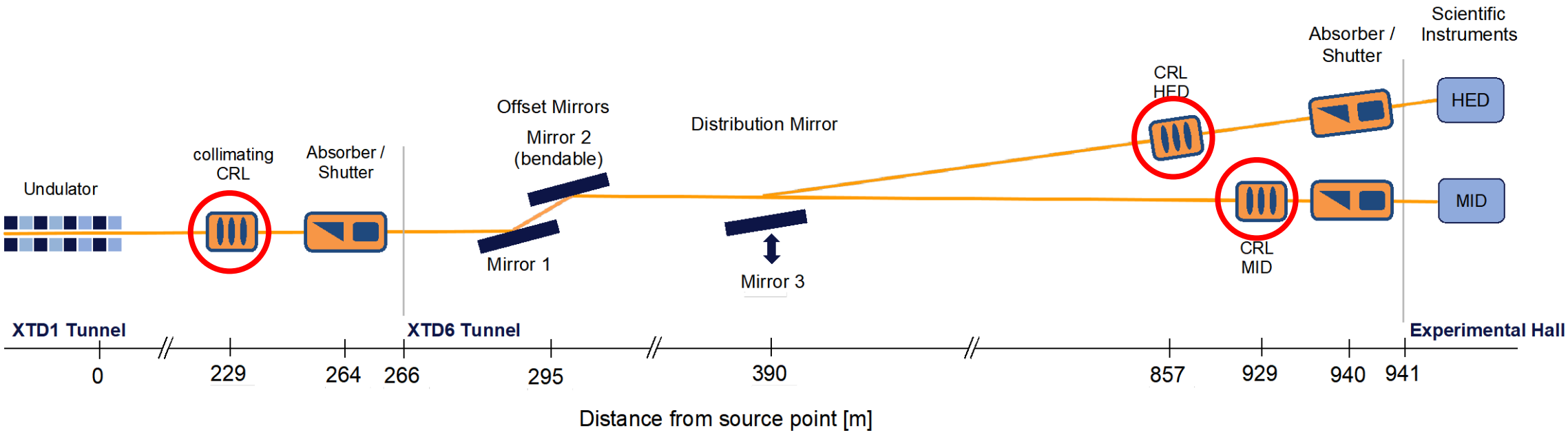
European XFEL beamline layout and experiment stations



Previous frontend design



Overview SASE2 beamline



- Problem: Focussing on beamshutters using XTD6 CRLs is possible
- Collimation of the beam with XTD1 CRL nessessary due to ultra long beamline
  - Change of wavelength will result in focussing!
- Beam might damage the shutter if focus positon is incorrect
- CRL need to be driven out of the beam to close shutter and access experimental hutch

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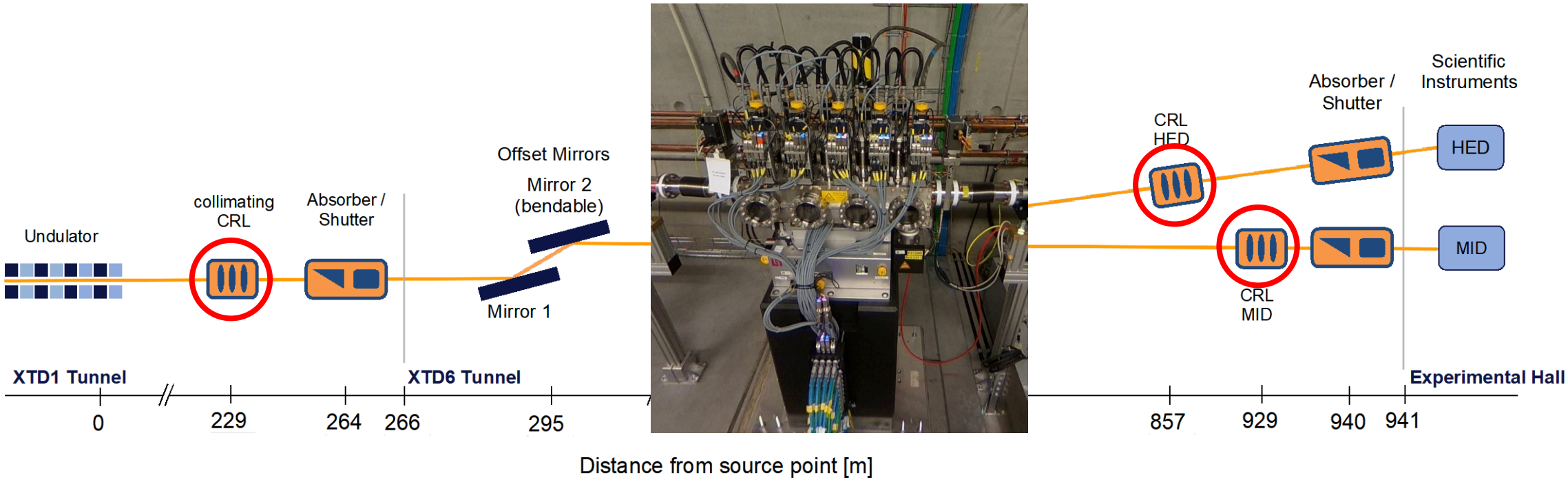

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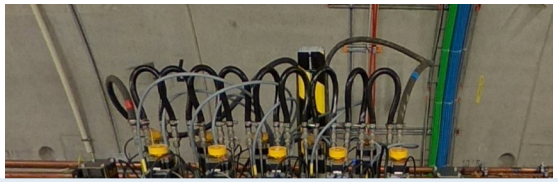

SASE2 operation constraints by safety group (03/2019):

Power restrictions:

For E = 7 to 8.1 keV: P_{max} = 2.5 W

For E > 8.1 keV: P_{max} = 4 W

+ several CRL arms disabled

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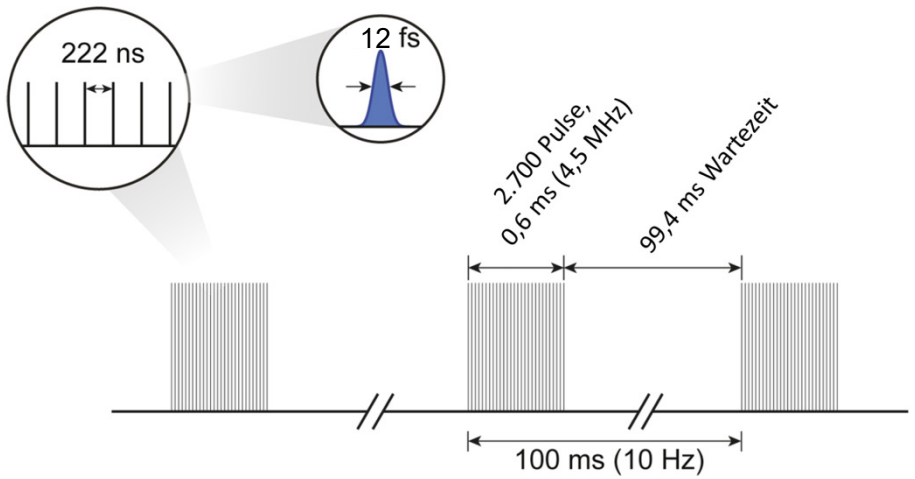
European XFEL key parameters

Superconducting LINAC, 10 Hz		
Length	km	2.1
max. Electron Energy	GeV	17.5
FEL beam		
Pulses per second	1/s	27.000
Photon Energy	keV	0.3 … 24
max. Pulse Energy	mJ	3.6 … 11
Pulse Duration	fs	< 100
max. Photons/Pulse		10^{12}
min. Focus ∅	µm	< 1

Photon Beam Pulse Pattern



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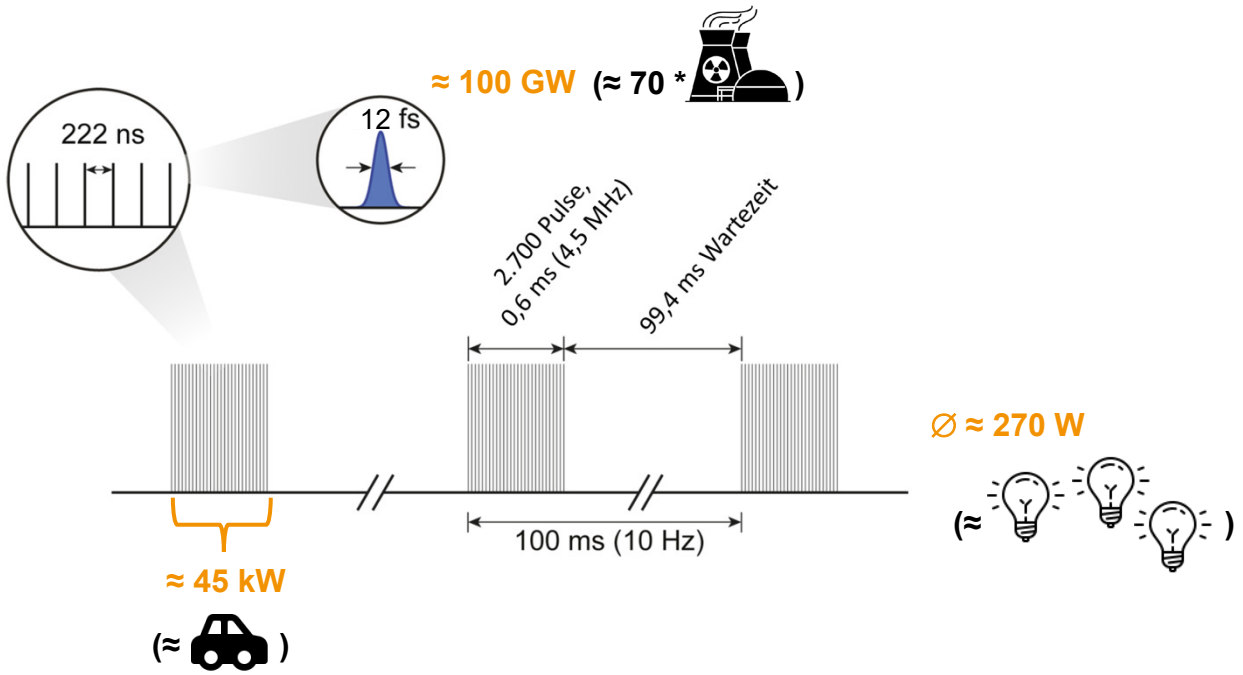
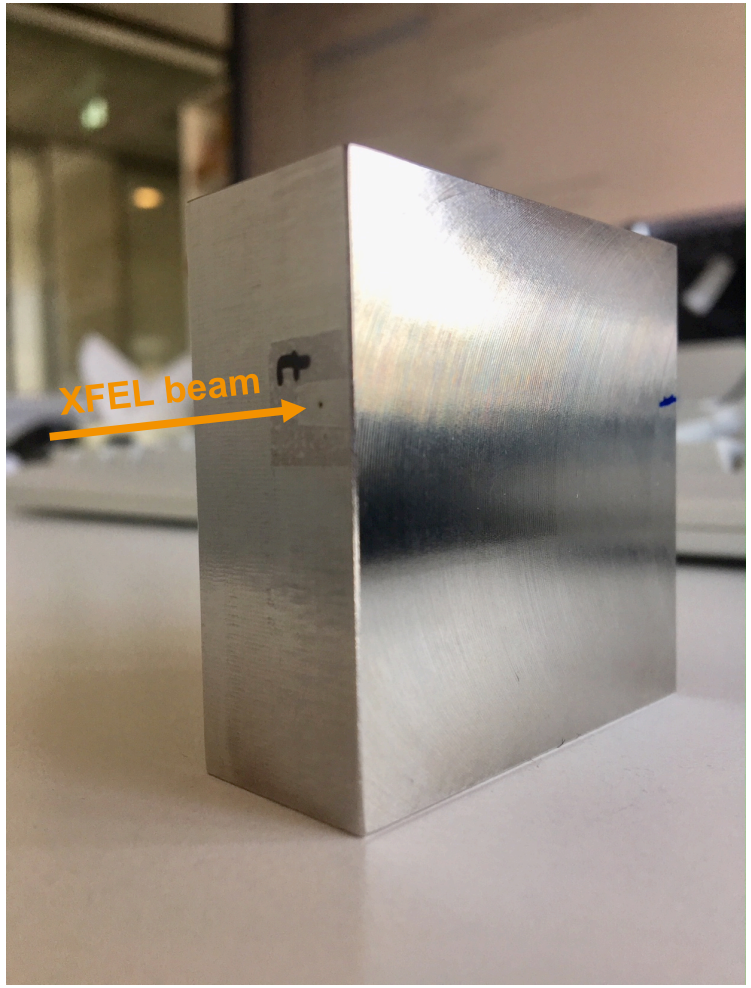


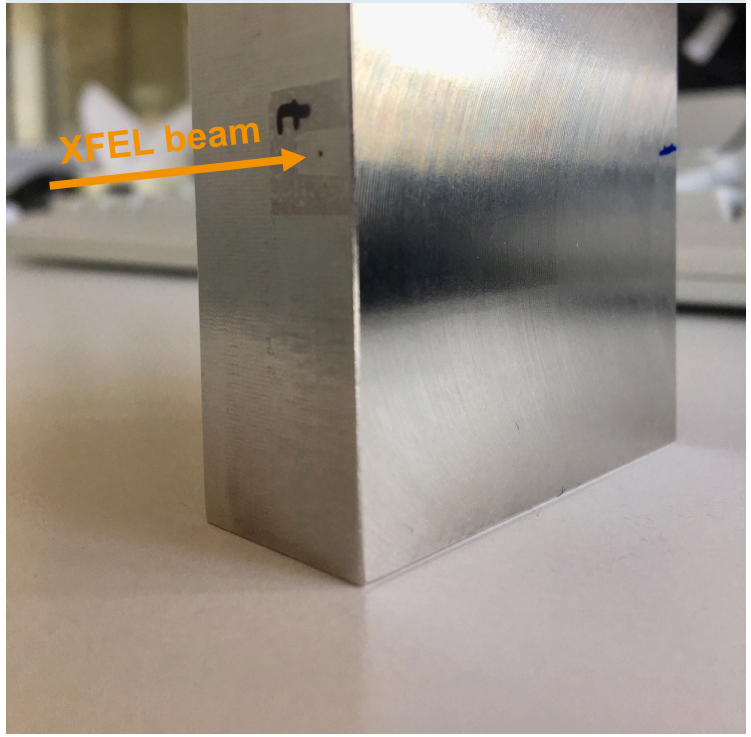
Material tests with focussed beam



A. Leuschner DESY, H. Sinn, F. Yang, SEC group, EuXFEL

Material tests with focussed beam

Drilling through 50 mm of steel @ SASE1:



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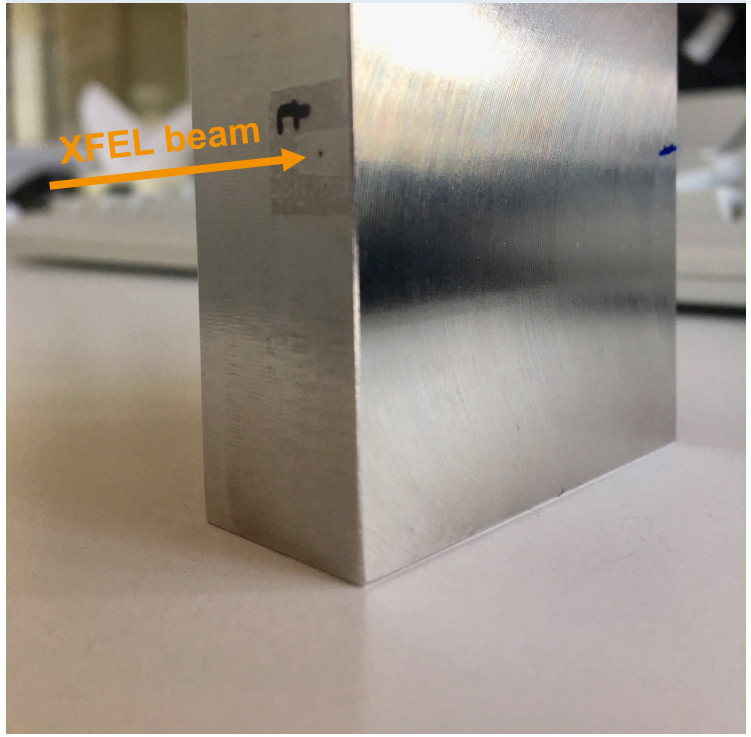
Material tests with focussed beam

Drilling through 50 mm of steel @ SASE1:

26 seconds



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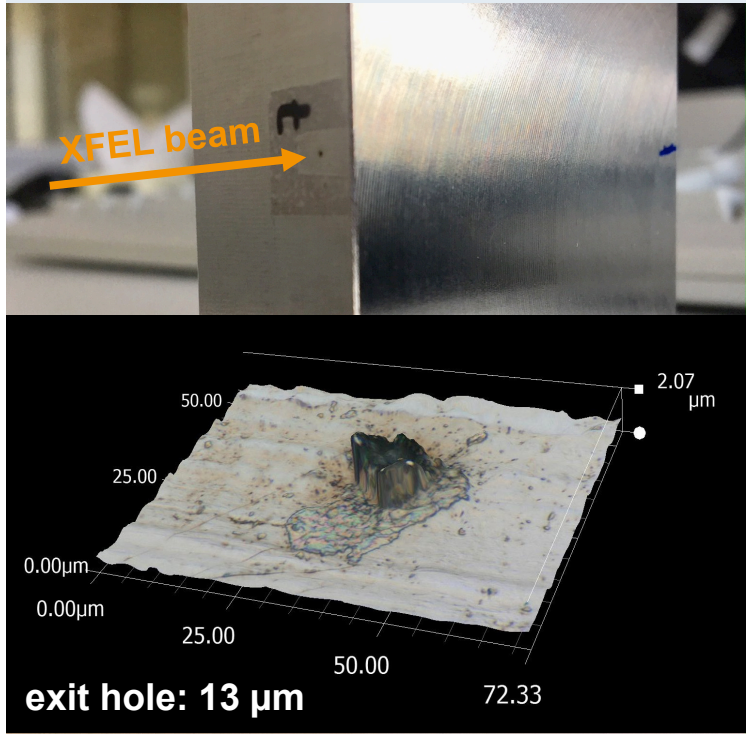

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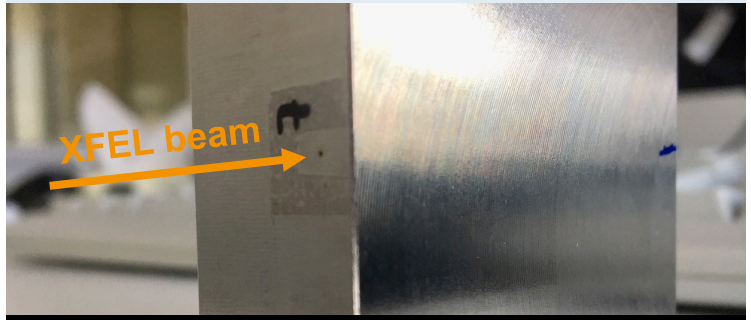

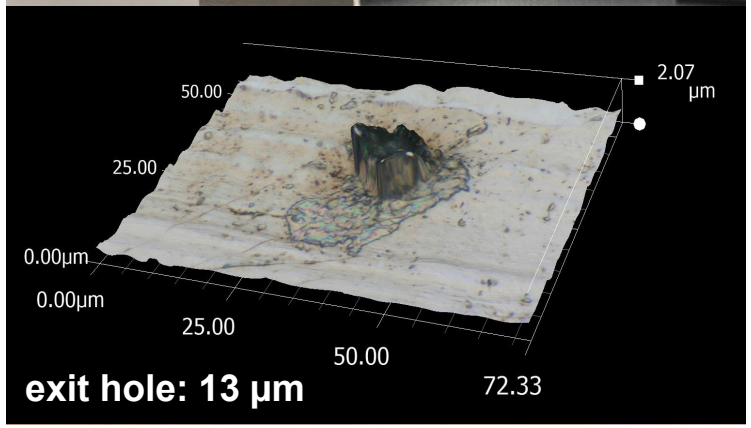

Drilling through 50 mm of copper @ SASE1:

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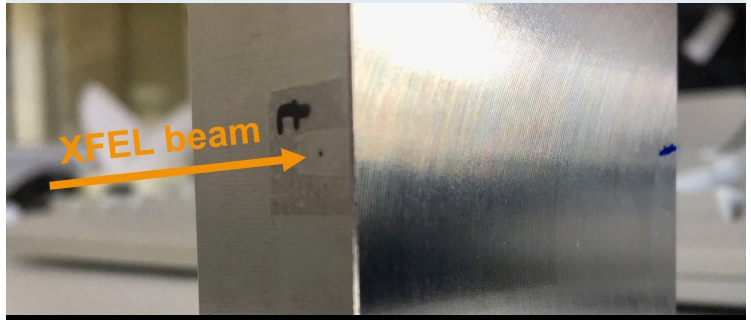

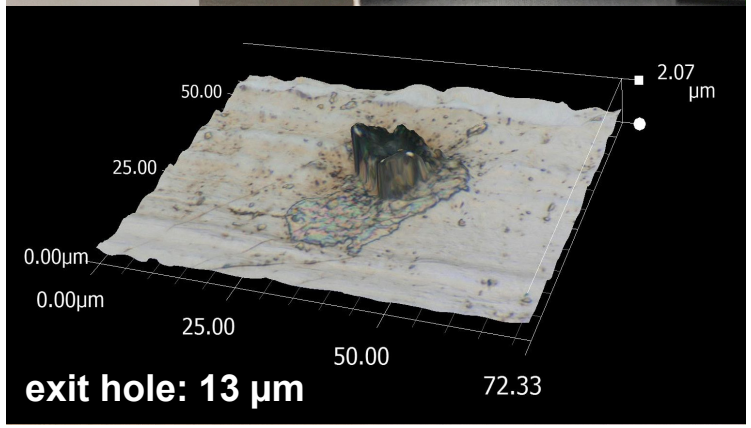

Drilling through 50 mm of copper @ SASE1:

3 seconds

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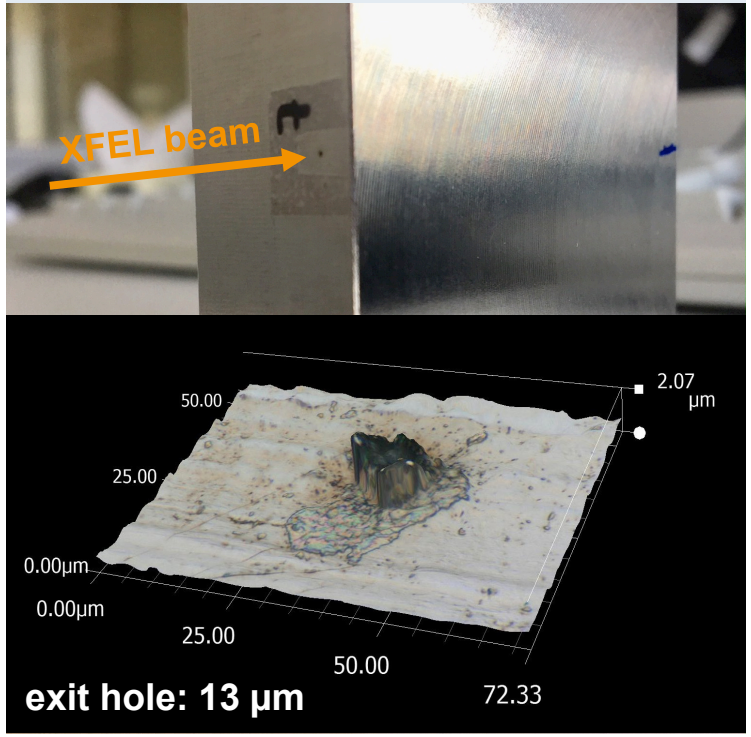

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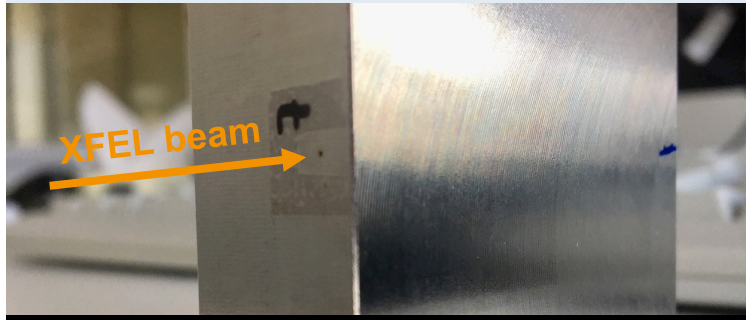

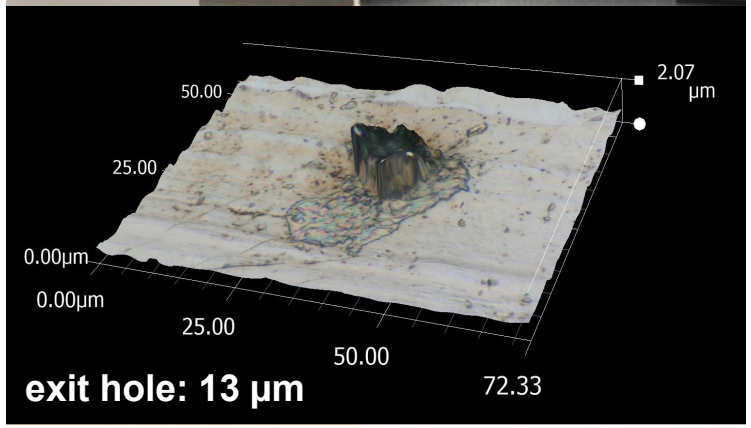

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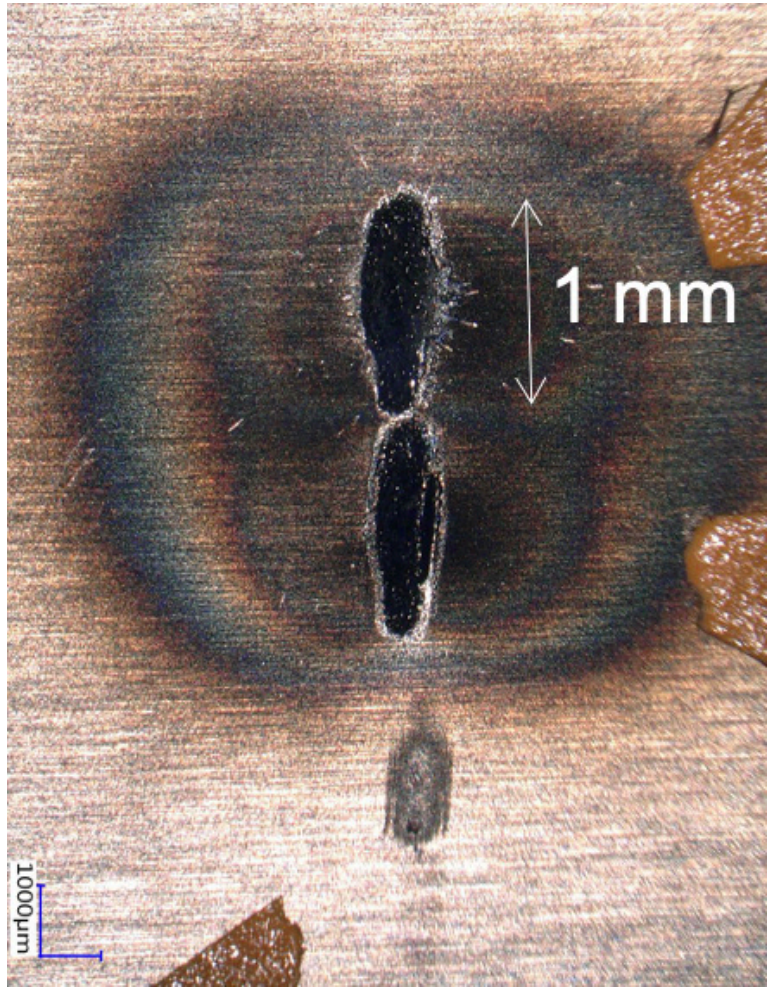

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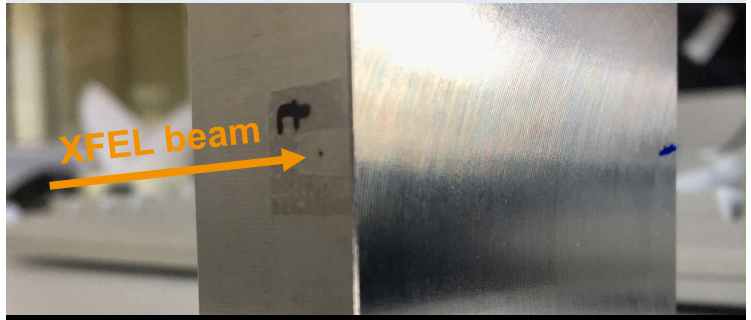

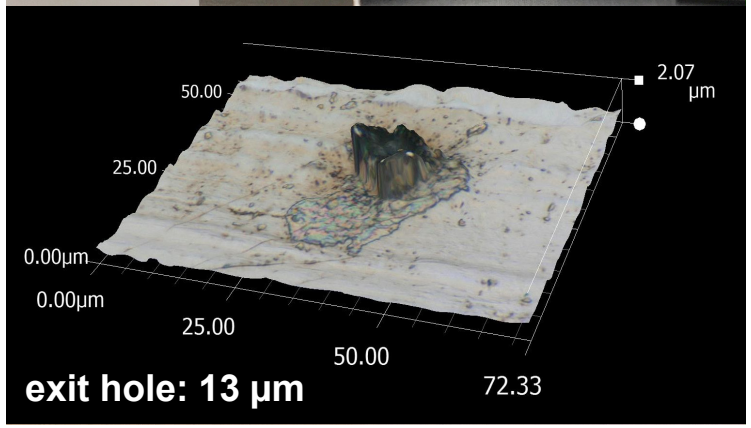

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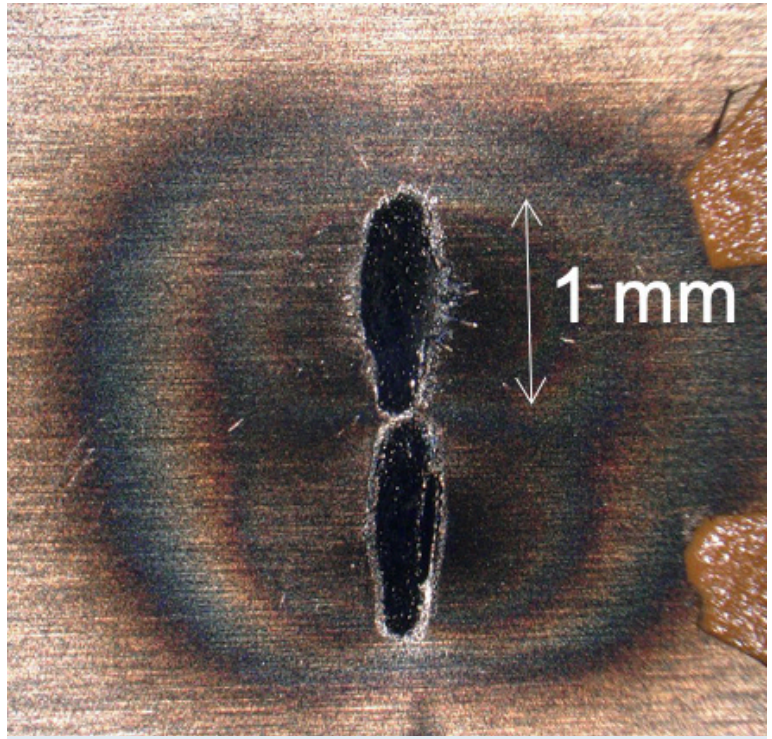

Drilling through 4 mm of B_4C @ SASE3:

A. Leuschner DESY, H. Sinn, F. Yang, SEC group, EuXFEL

Material tests with focussed beam

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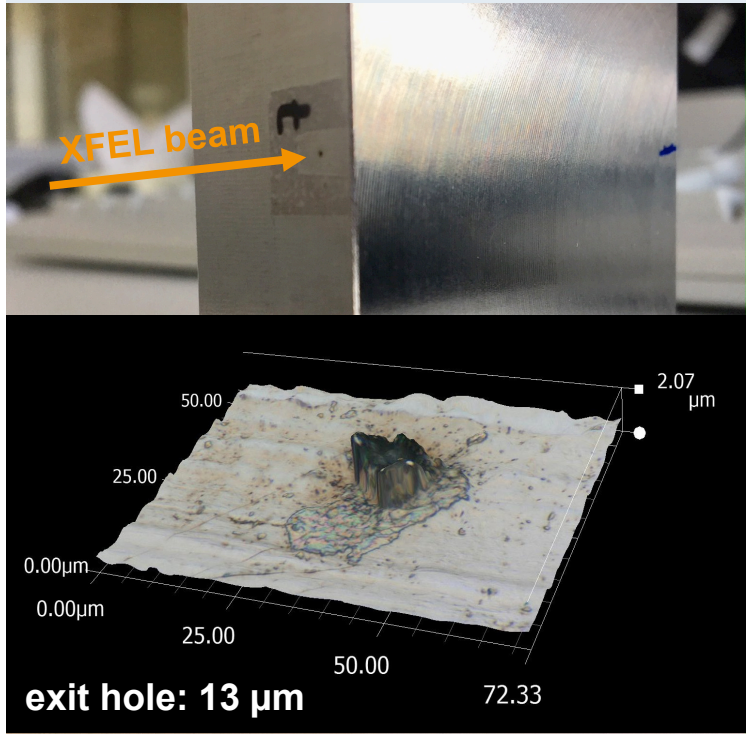

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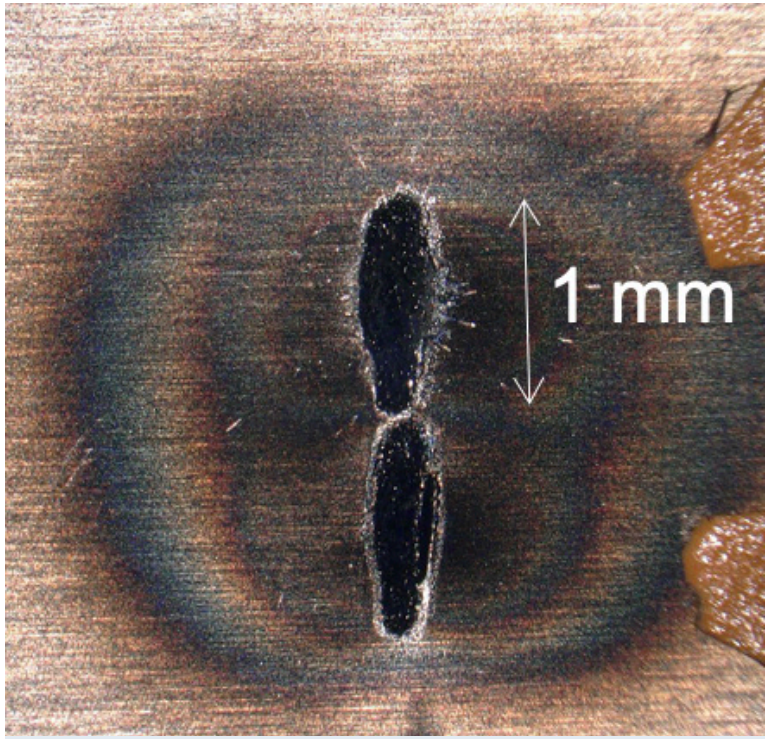


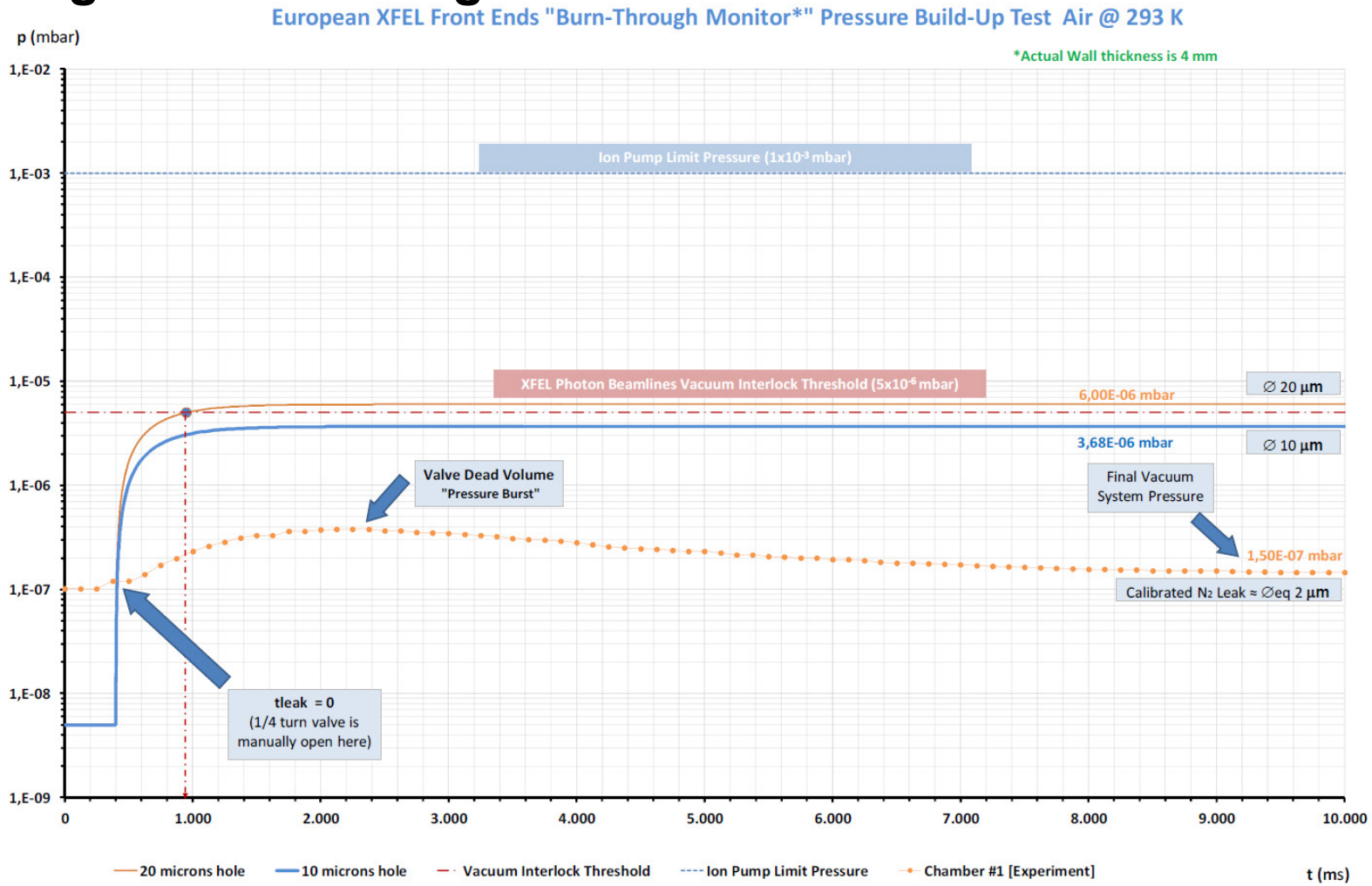
Drilling through 4 mm of B_4C @ SASE3:

10 minutes

A. Leuschner DESY, H. Sinn, F. Yang, SEC group, EuXFEL

Consequences on the burn through monitor design

- Simulations show that the passive burn-through-monitors will not work with holes smaller than 20 µm because such a vacuum leak would be too small to trigger the valves to close and to revoke beam permission.
- Setting a lower threshold for the vacuum interlock would not work reliably.



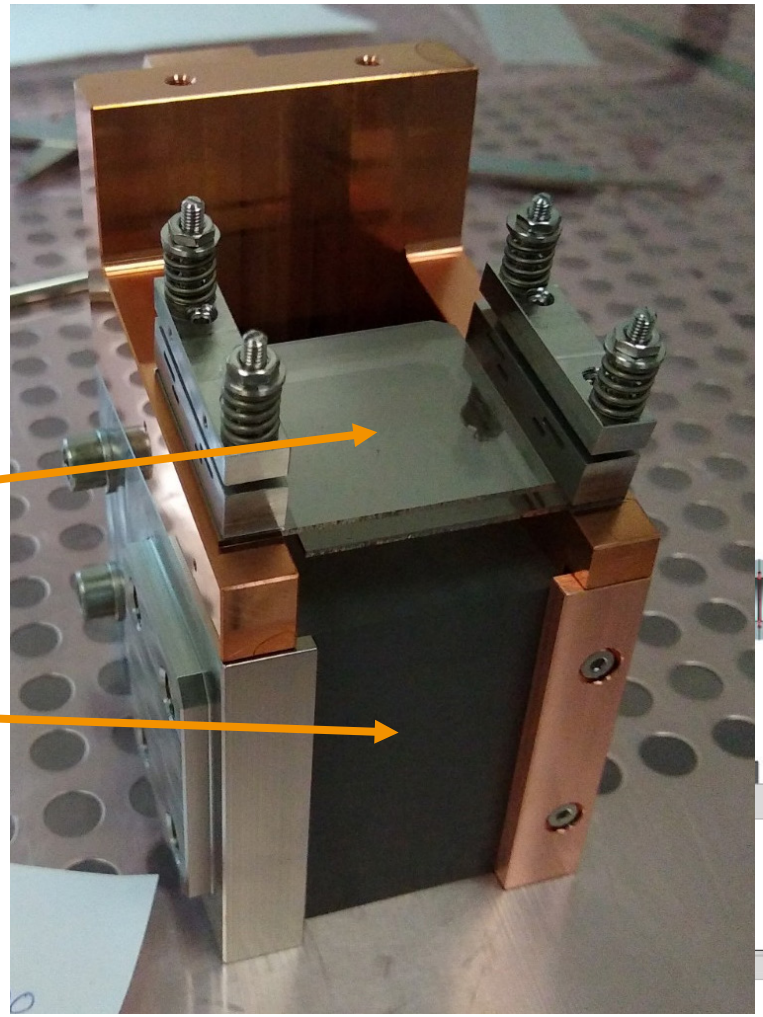
R. Villanueva, EuXFEL Vacuum group

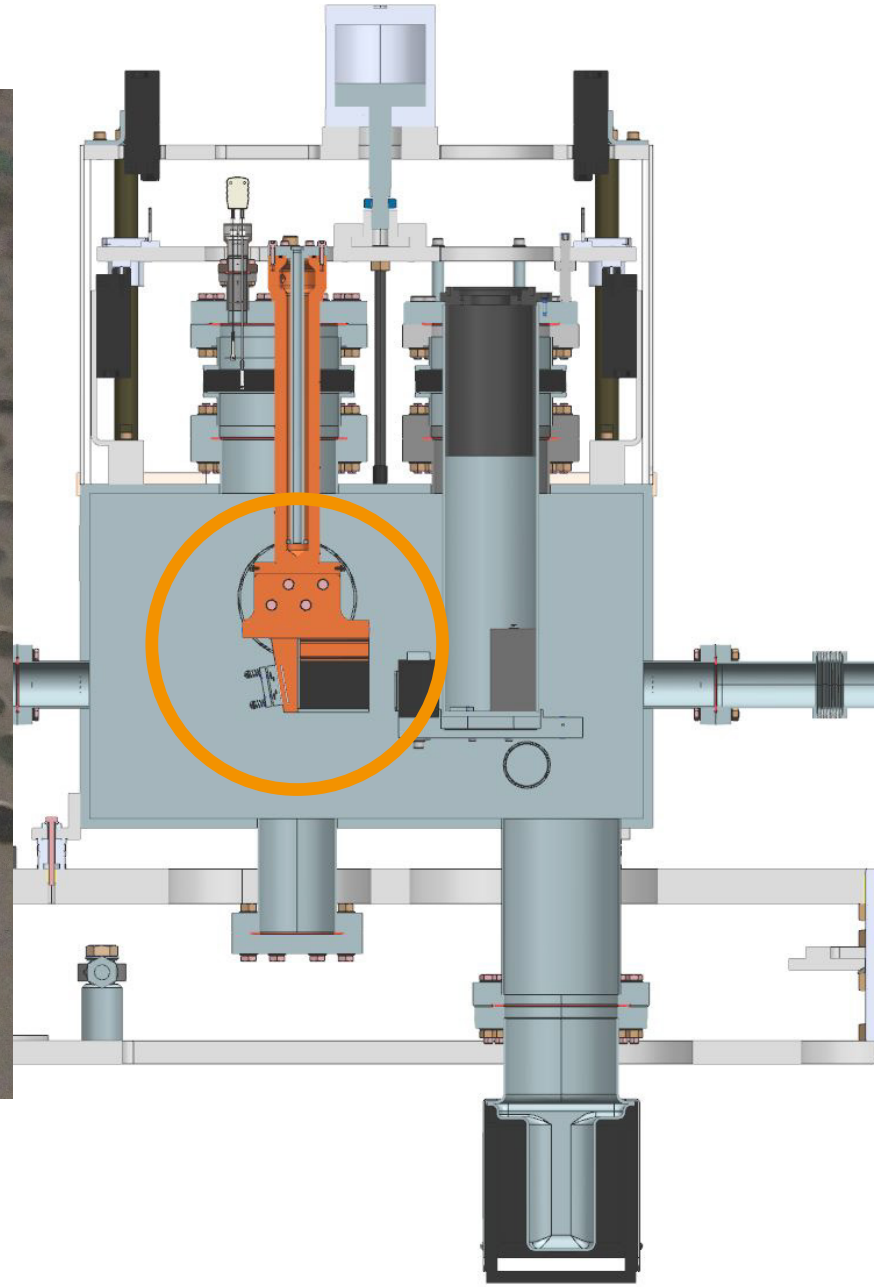
Conclusions from material tests

- One can drill with X-rays 50 mm (possibly more) deep holes into copper and steel with a diameter of about 20 µm
- The passive burn-through-monitor will not work reliably with holes smaller than 20 µm because the vacuum leak would be too small
- The boron carbide (B_4C) absorber needs some protection
- A new frontend design is needed to lift the operation constrains

New frontend design

- **Tungsten shutter remains as it is**
  (not shown here)
- **New absorber:**
  - 2 CVD diamond plates
    - ► 2 mm thick
    - ► Each clamped from one side
  - 60 mm B_4C block





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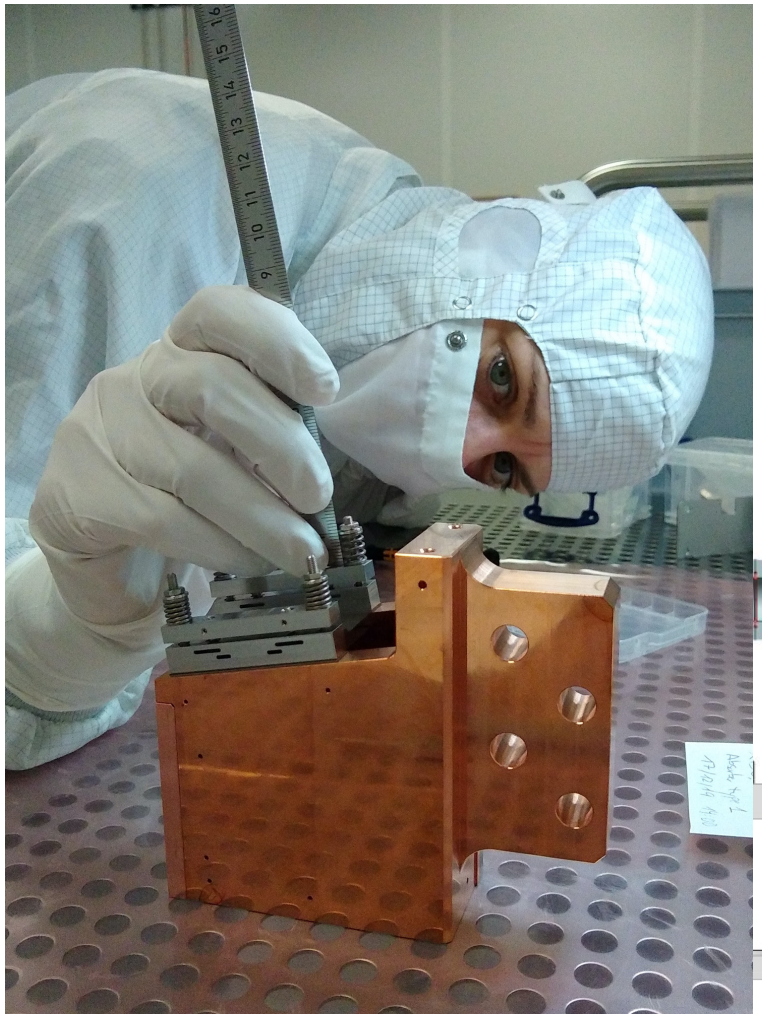
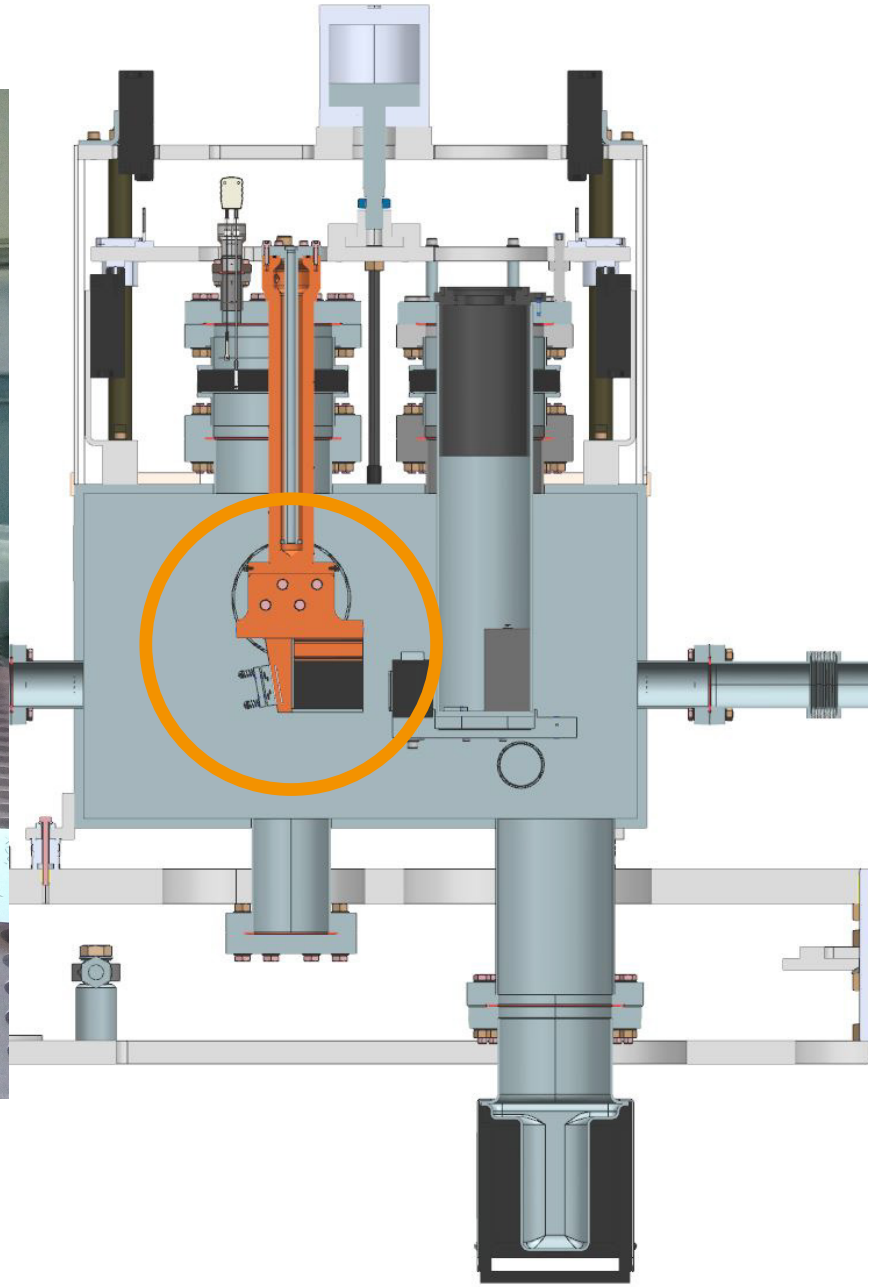
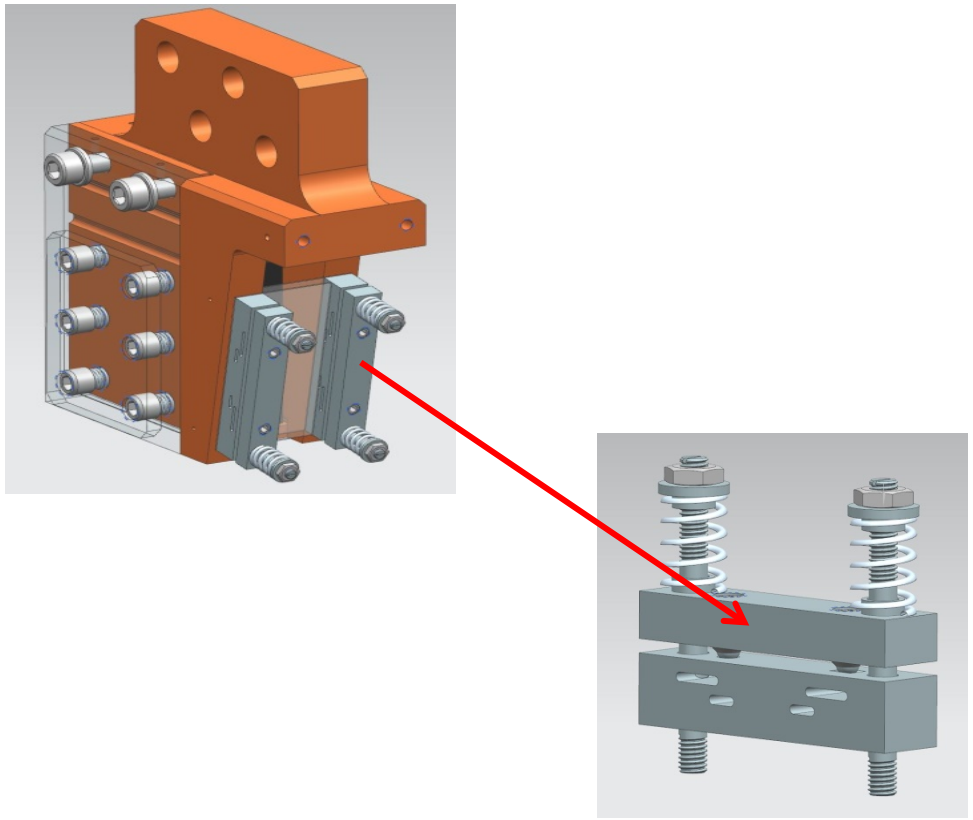
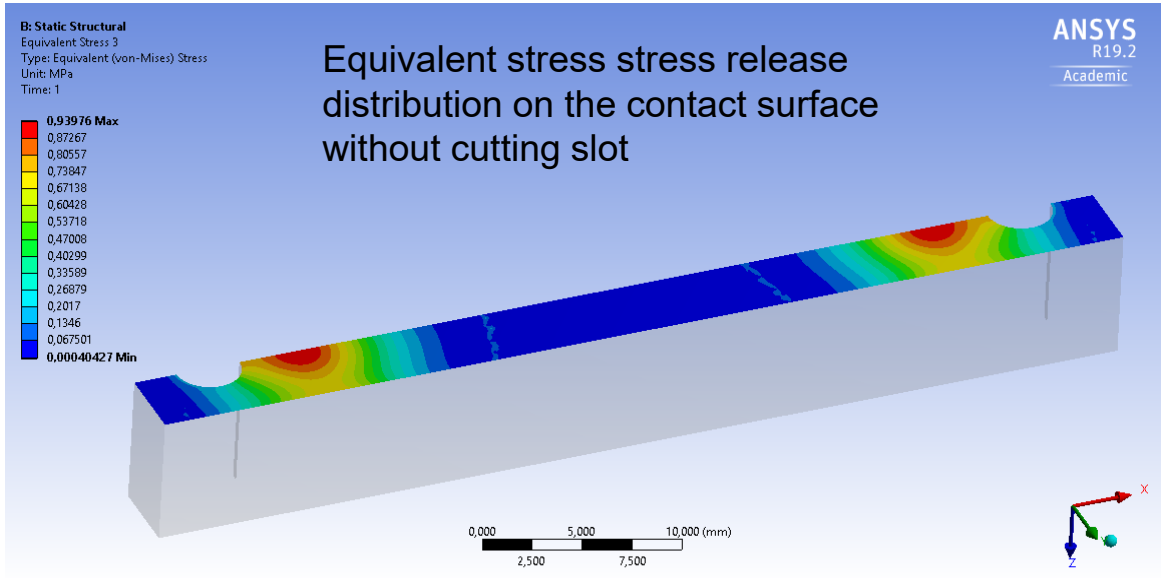
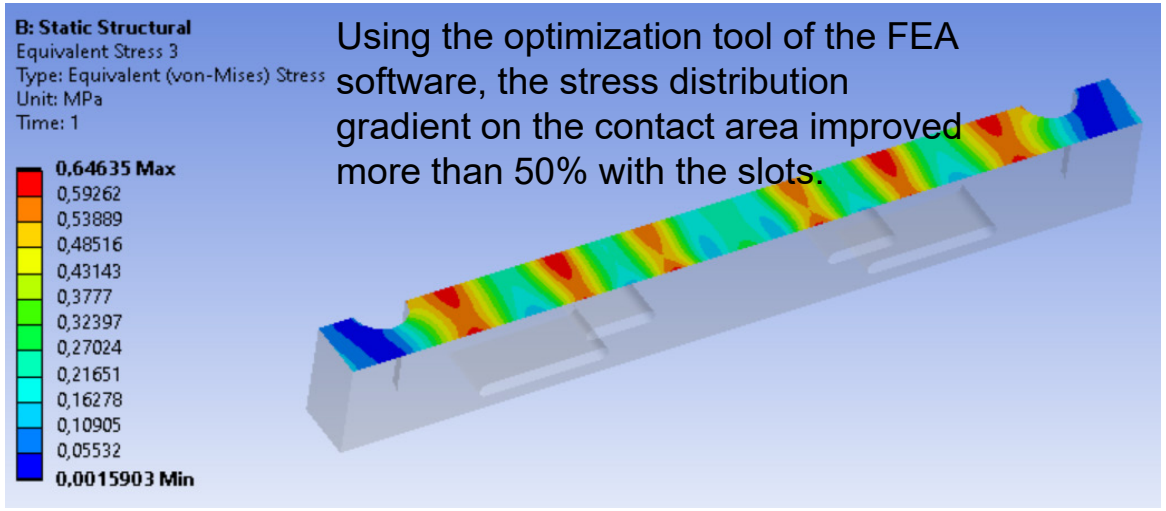




Clamping mechanism for diamond plates





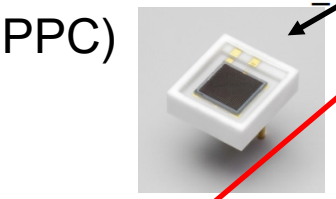


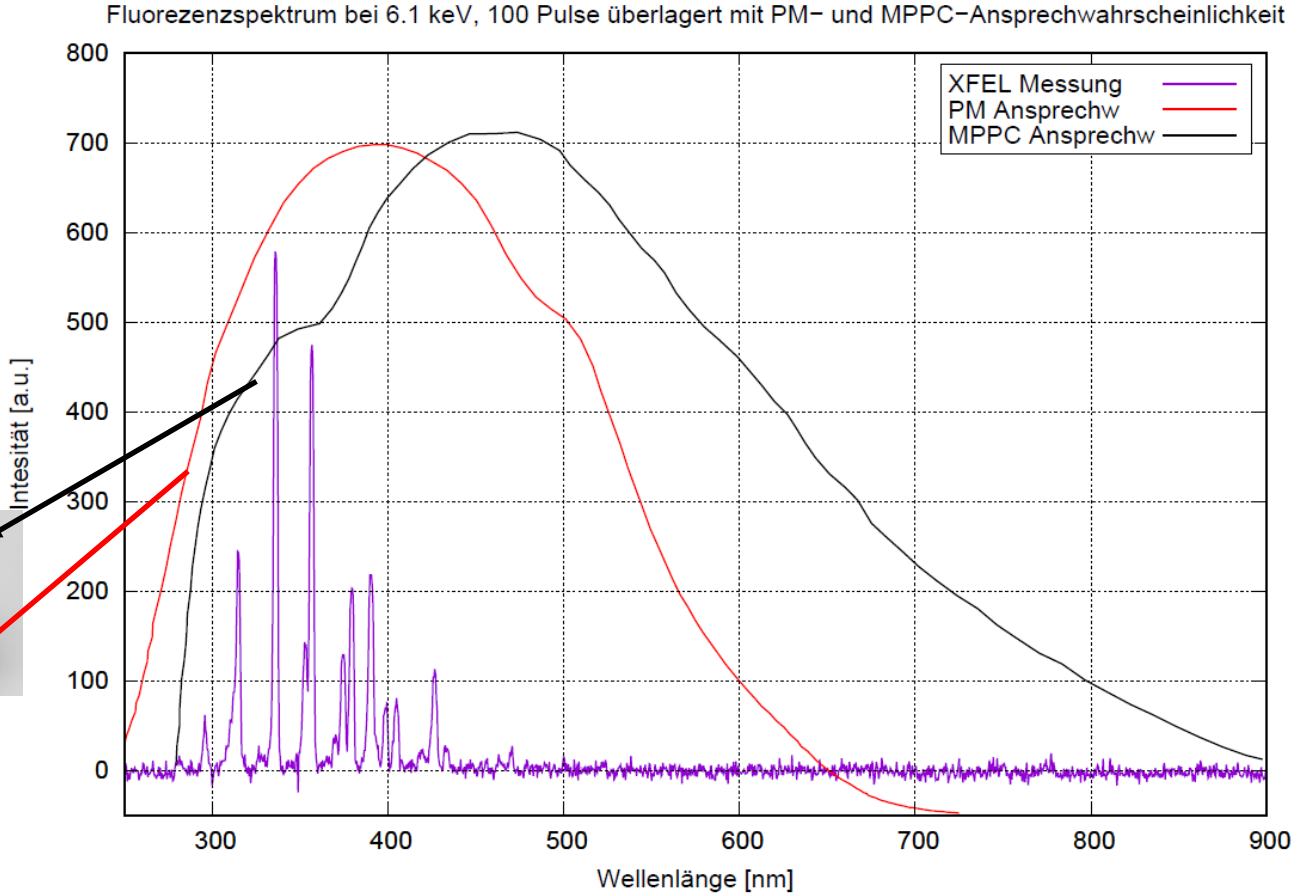
Fan Yang, EuXFEL Mechanical Engineering group

Fluorescence from XFEL beam in air (@SASE3: E = 2.66 keV)

Fluorescence from XFEL beam

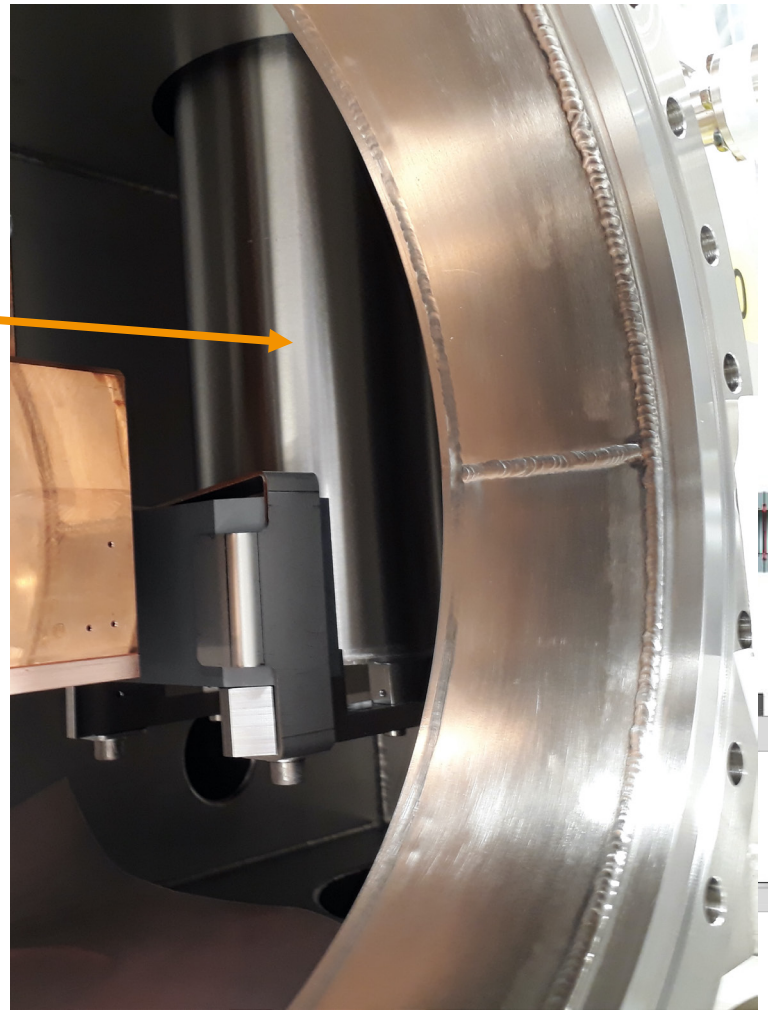
- We measured fluorescance spectra of the beam (purple line)
  - Intensity maxima are in the UV and blue range between 270 nm and 430 nm
- Two sensors were selected to detect the light:
  - Multi Pixel Photon Counter (MPPC)
    - ► Hamamatsu S13360-50CS
  - Photomultiplier (PM)
    - ► Hamamatsu H11901-110

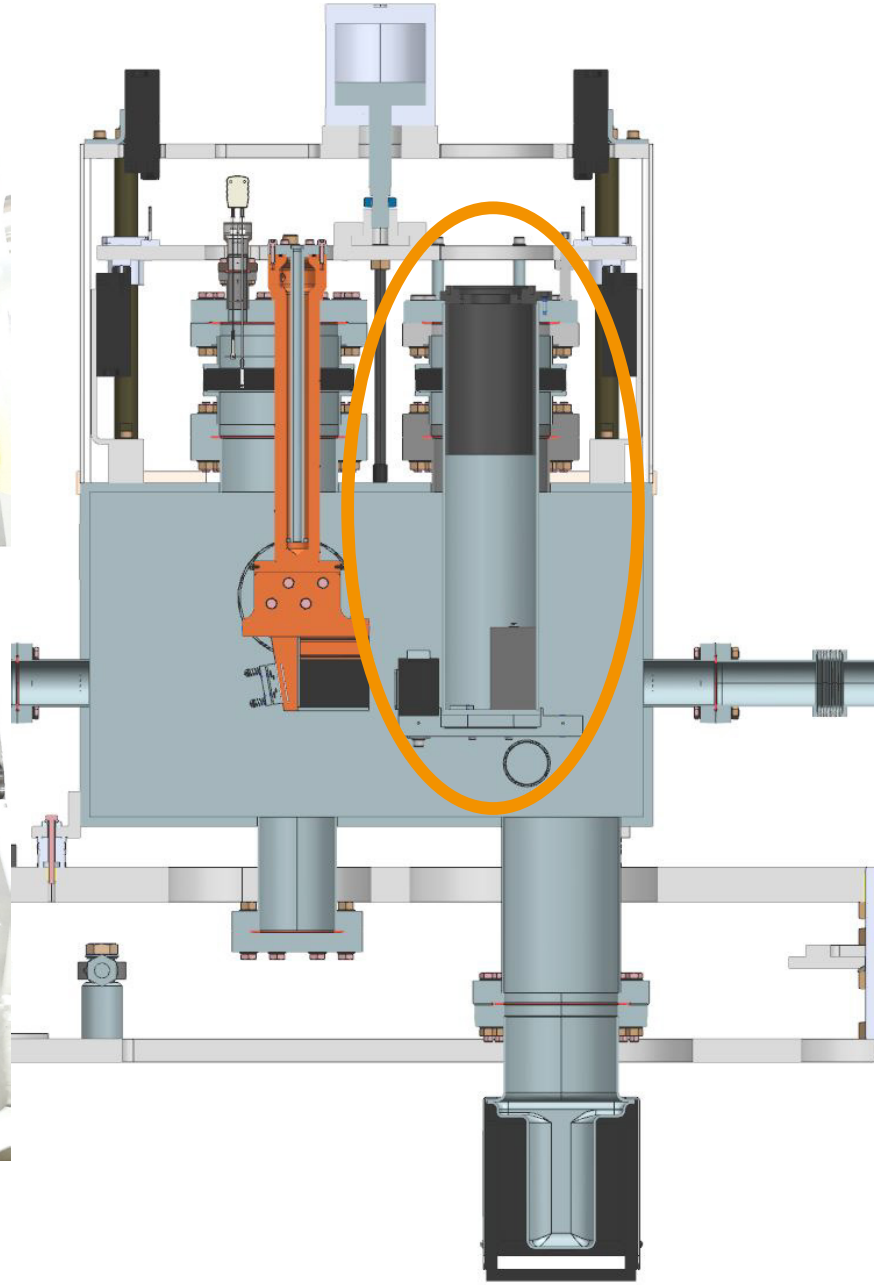




New frontend design (2)

- **New burn-through system:**
  - Pipe insert





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- **New burn-through system:**
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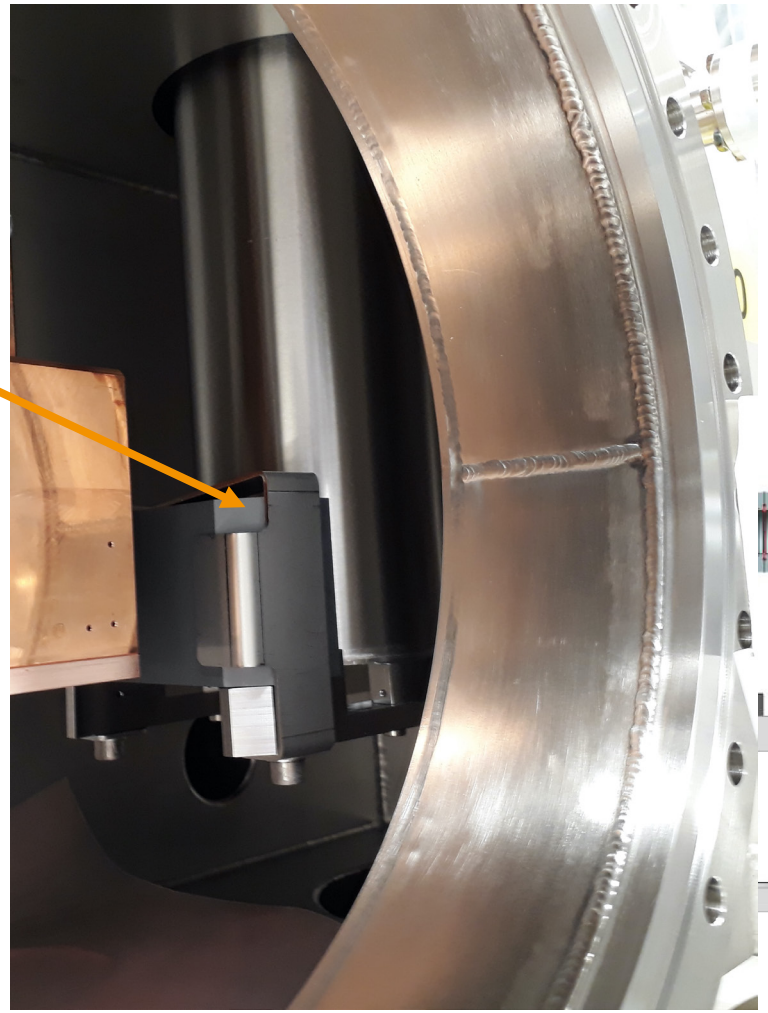
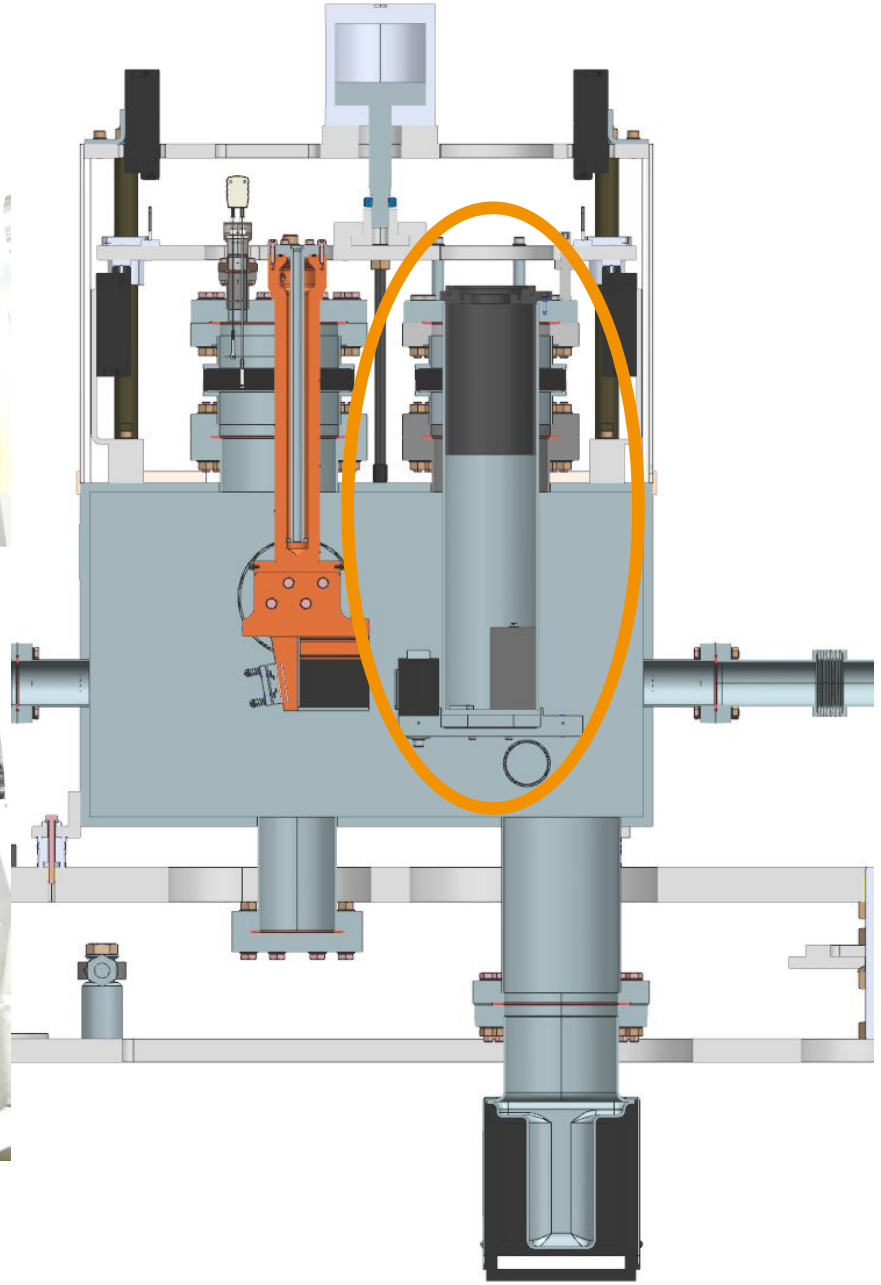
  - B_4C block 35 mm (in vacuum)





New frontend design (2)

- **New burn-through system:**
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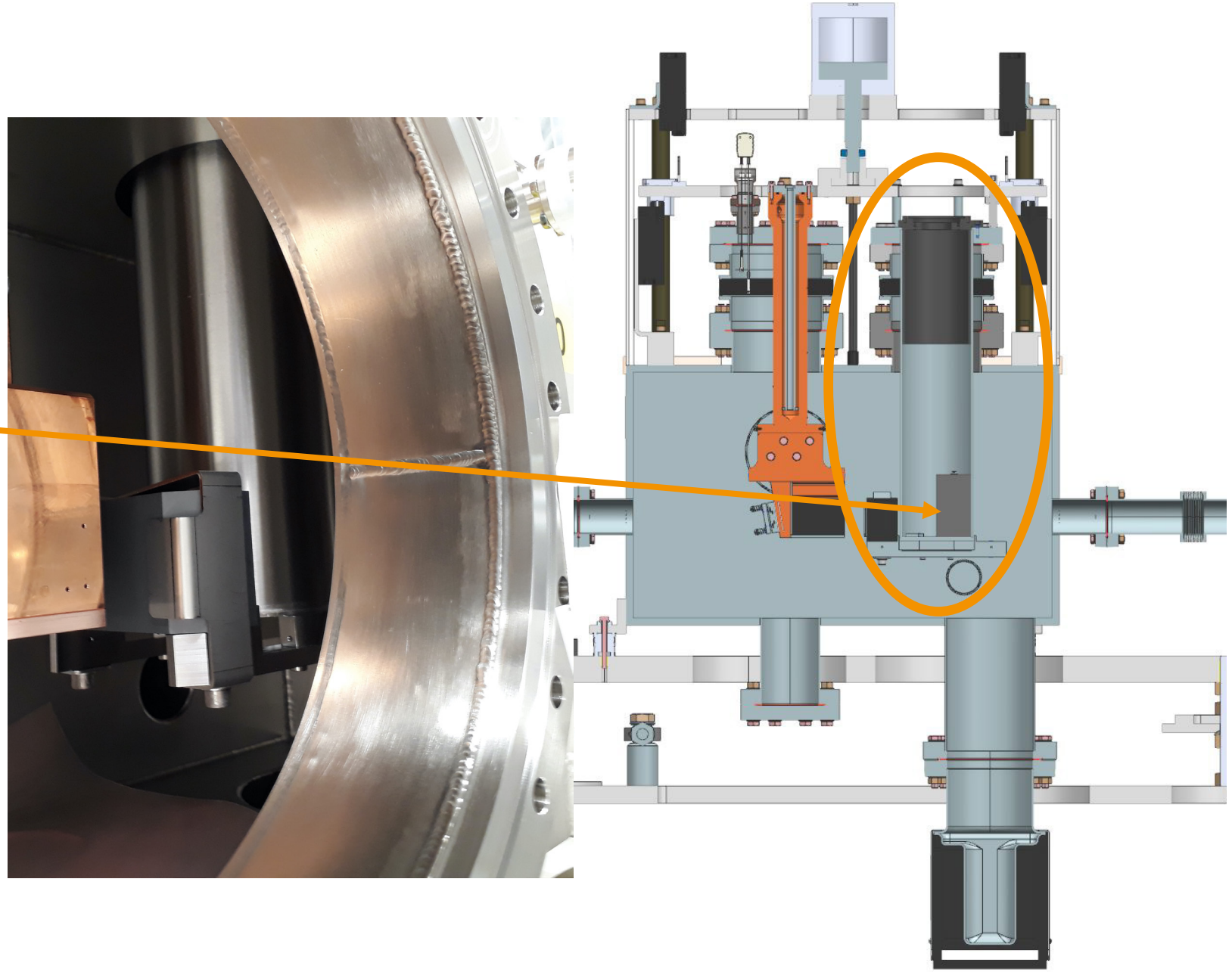
  - B_4C block 35 mm (in vacuum)
  - Graphite block 40 mm (in air)



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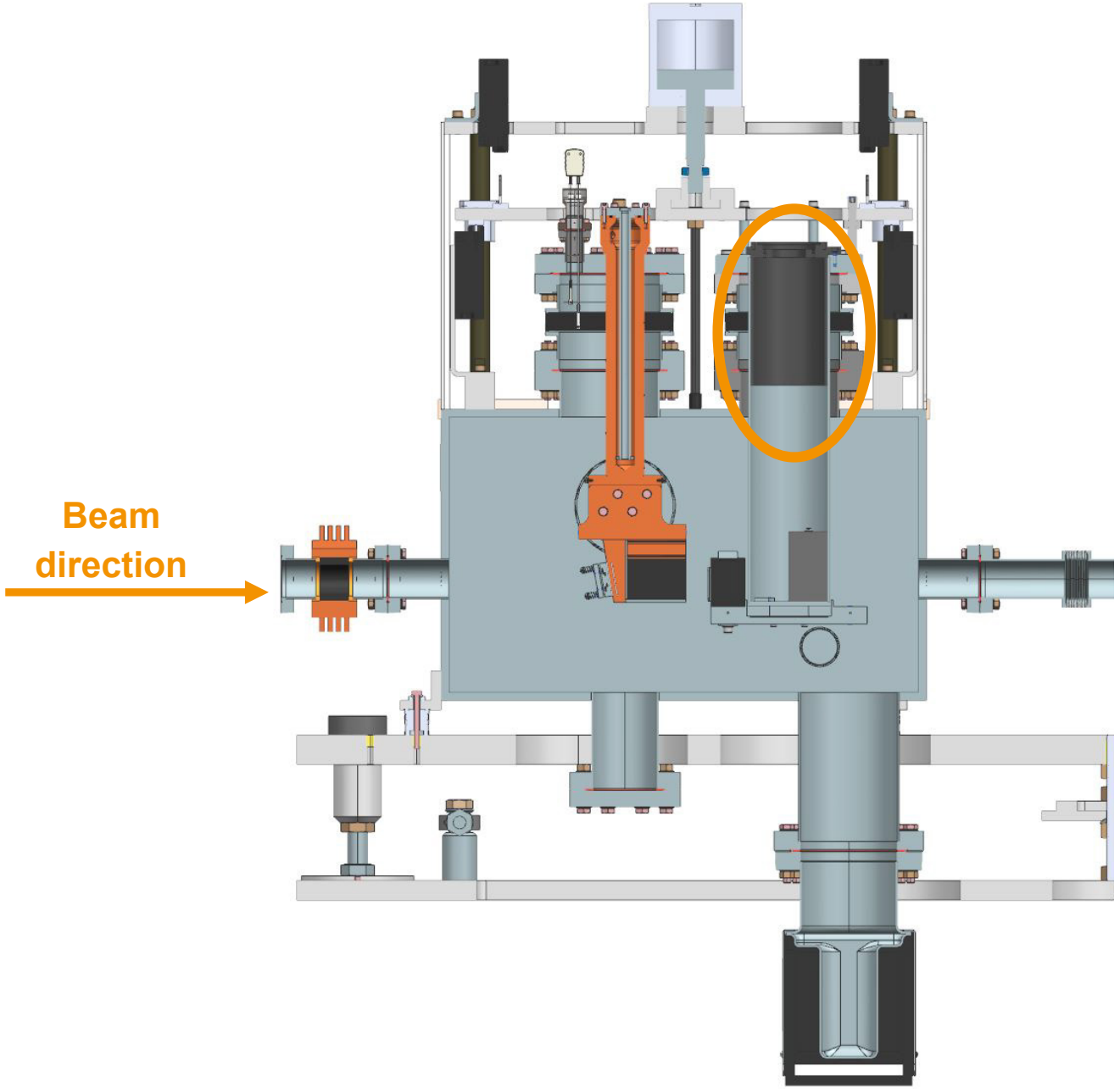
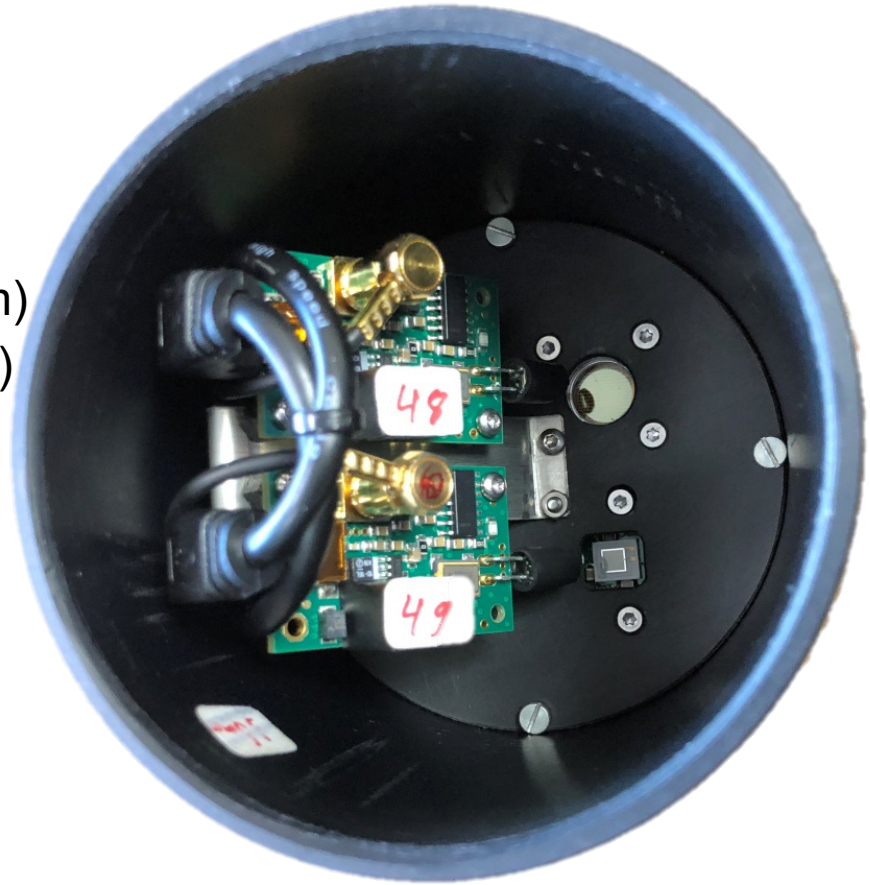
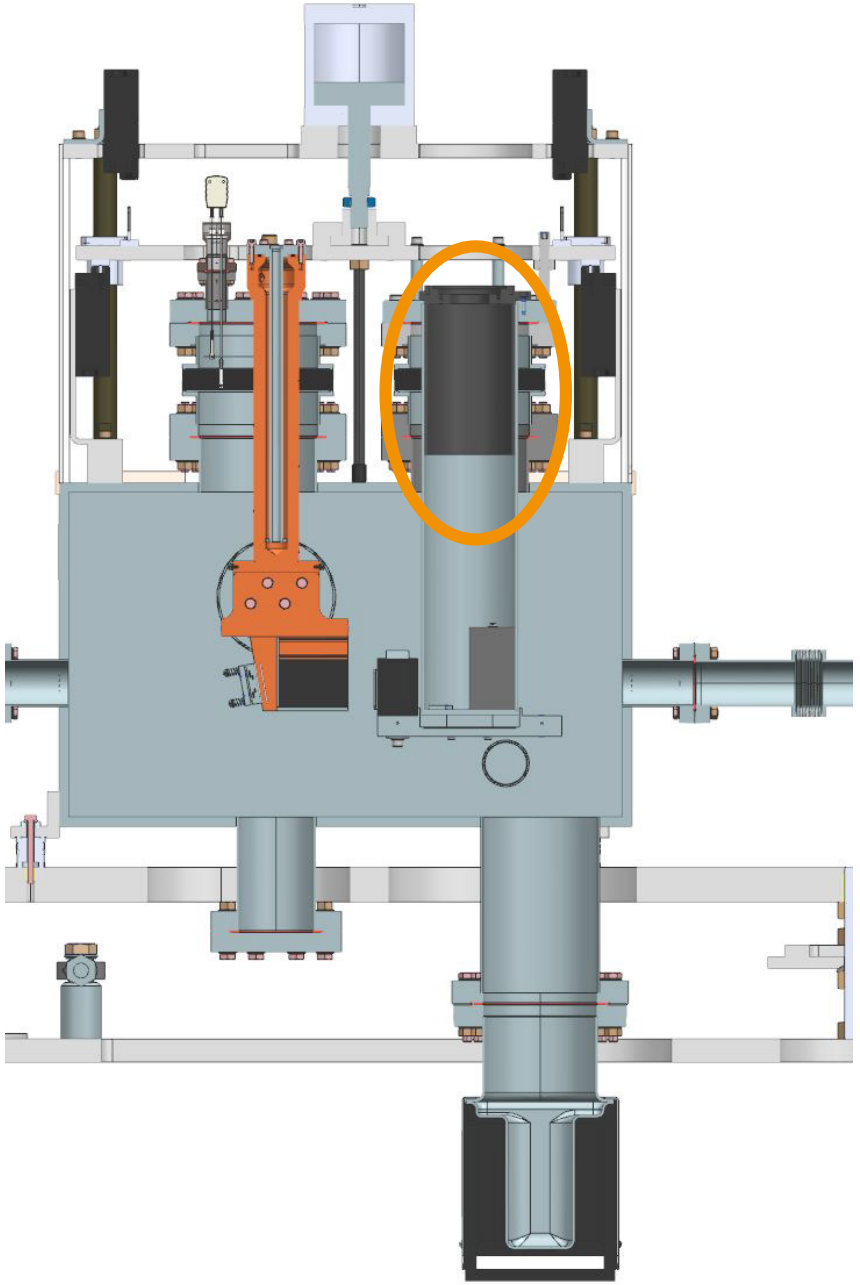


New frontend design (2)

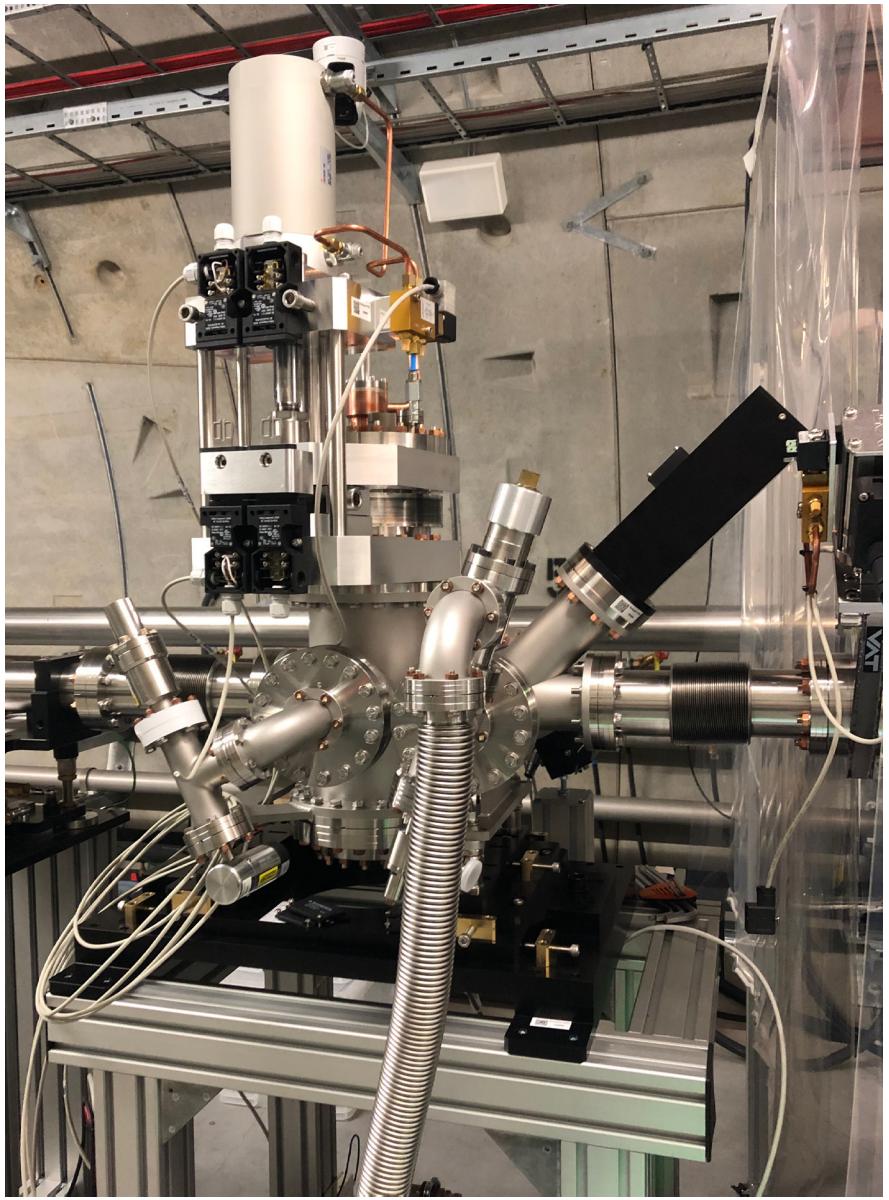
- **New burn-through system:**
  - Pipe insert
  - B_4C block 35 mm (in vacuum)
  - Graphite block 40 mm (in air)
- **New burn-through detectors by DESY D3:**
  - Redundancy
  - Build-in LEDs for repetitive self-test





Pre absorber installation

- Closed to focussing elements in the tunnels
- Similar design to absorber at frontend
- It does not serve personal safety
  - No burn through monitor
  - No Tungsten shutter
  - It protects safety equipement



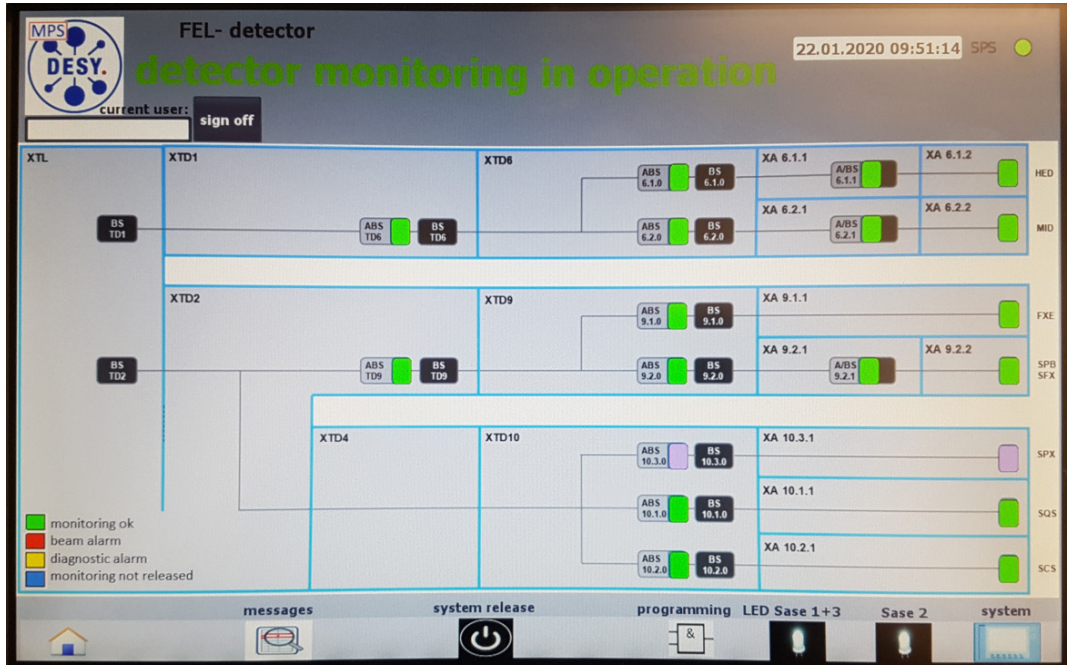
Summary (after 3.5 years of operation)

- 12 absorbers have been modified during one winter maintenance period
- 4 pre-absorber have been installed nearby CRL systems to ensure safe operation of the shutters

Installation in XS2 shaft building

Summary (after 3.5 years of operation)

- 12 absorbers have been modified during one winter maintenance period
- 4 pre-absorber have been installed nearby CRL systems to ensure safe operation of the shutters
- **Good news: No burn through yet!**
- Operation constrains on CRLs were lifted, all focussing options available
  - Only remaining constrain for beamline operation:
    The maximum photon beam power may not exceed 40 W



Summary (after 3.5 years of operation)

- 12 absorbers have been modified during one winter maintenance period
- 4 pre-absorber have been installed nearby CRL systems to ensure safe operation of the shutters
- **Good news: No burn through yet!**
- Operation constrains on CRLs were lifted, all focussing options available
  - Only remaining constrain for beamline operation:
    The maximum photon beam power may not exceed 40 W

XFEL beam can drill through (almost) every solid material!

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Thank you for your attention